中国科学技术大学
University of Science and Technology of China

DARK MATTER PARTICLE EXPLORER (DAMPE)

Researches on the Response to High-Energy Electrons of the VLAST High-Granularity Electromagnetic Calorimeter Prototype

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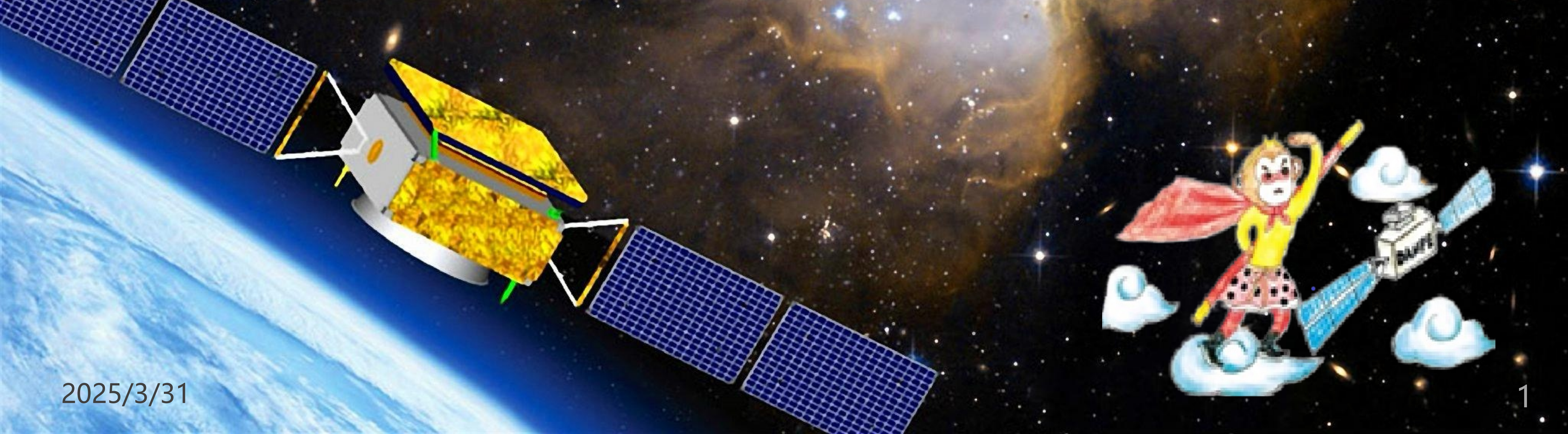

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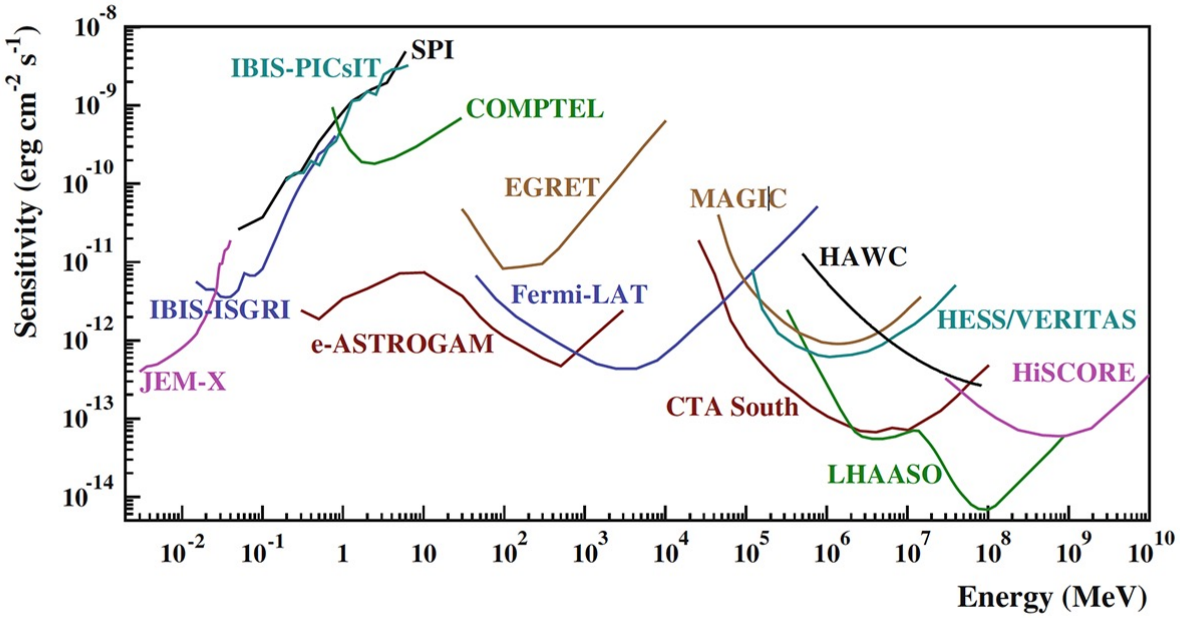
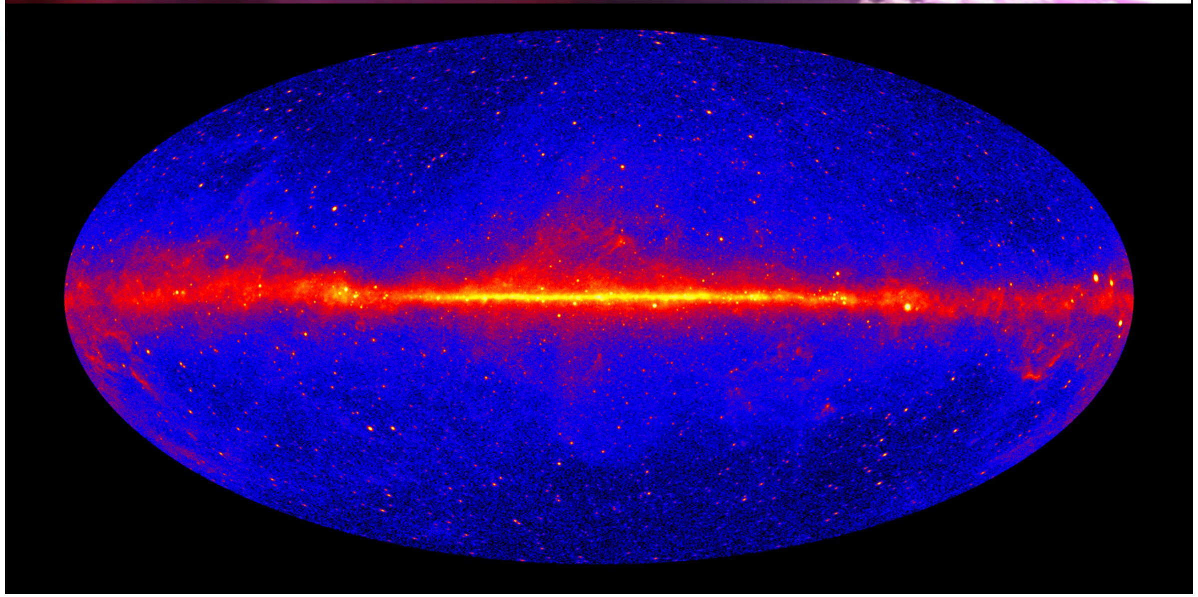
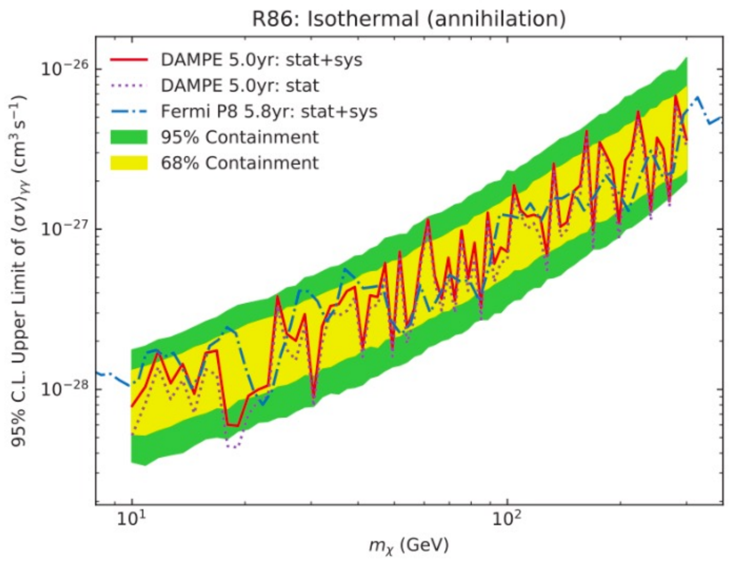
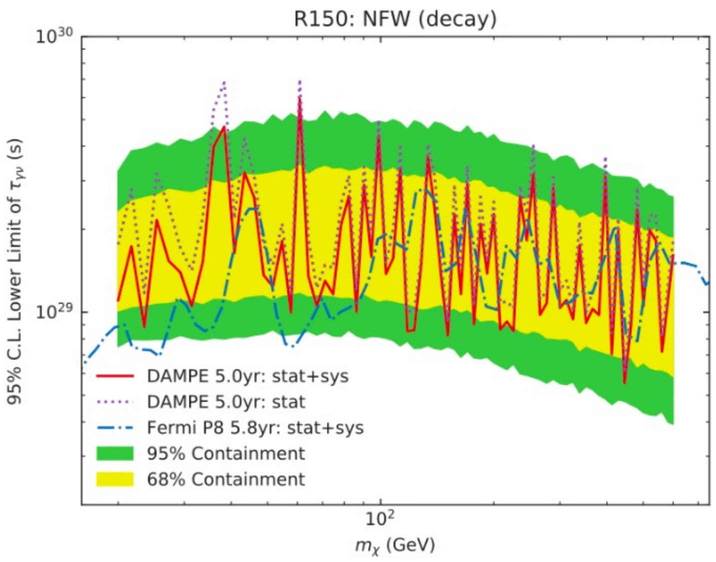


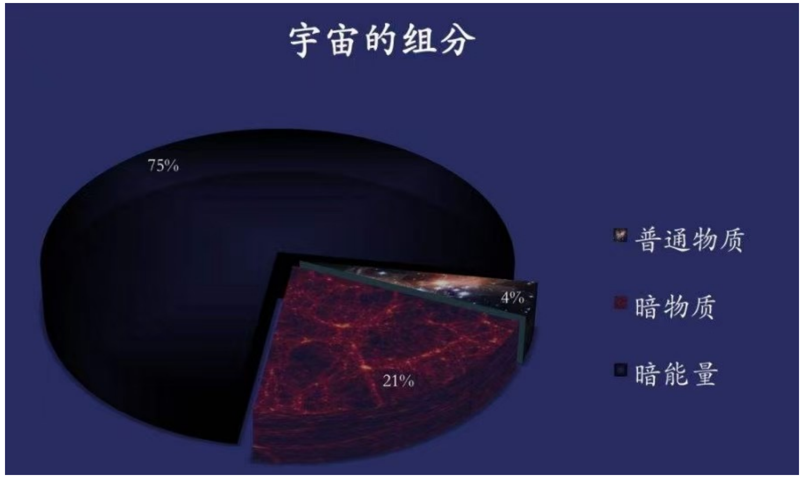


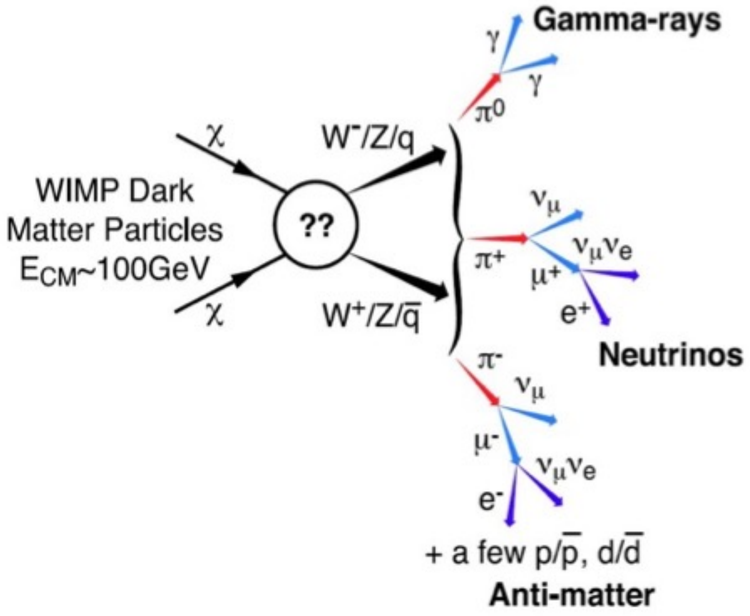
- **High energy gamma-rays** could be produced in the interaction about high energy particles accelerated by **extreme astronomical objects**.
- Precise measurements of spectra of high energy gamma-rays are crucial to understand **the astronomical radiation process**

Dark Matter Indirect Detection



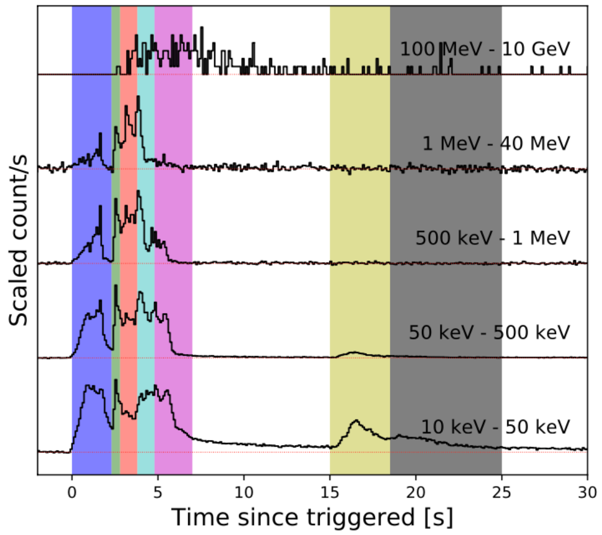


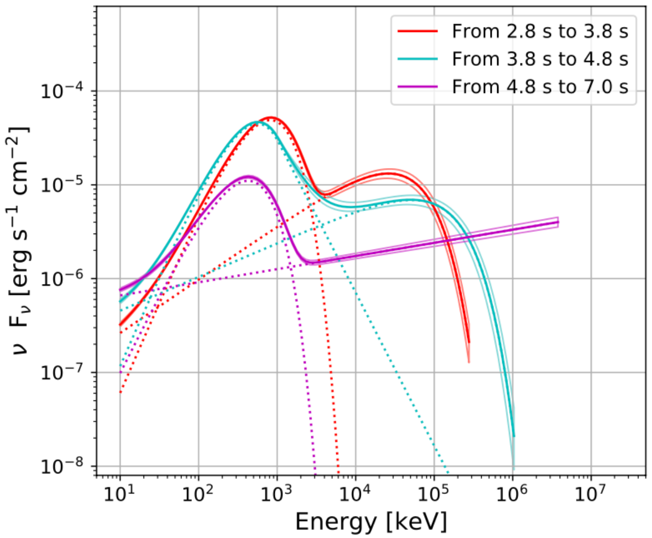




- Dark matter can annihilate to **mono-energetic gamma-ray lines** via the processes $\chi\chi\rightarrow\gamma\gamma$ and $\chi\chi\rightarrow\gamma Z$
- The **galactic center** is an interesting regions for the indirect detection of dark matter

Gamma-Ray Burst

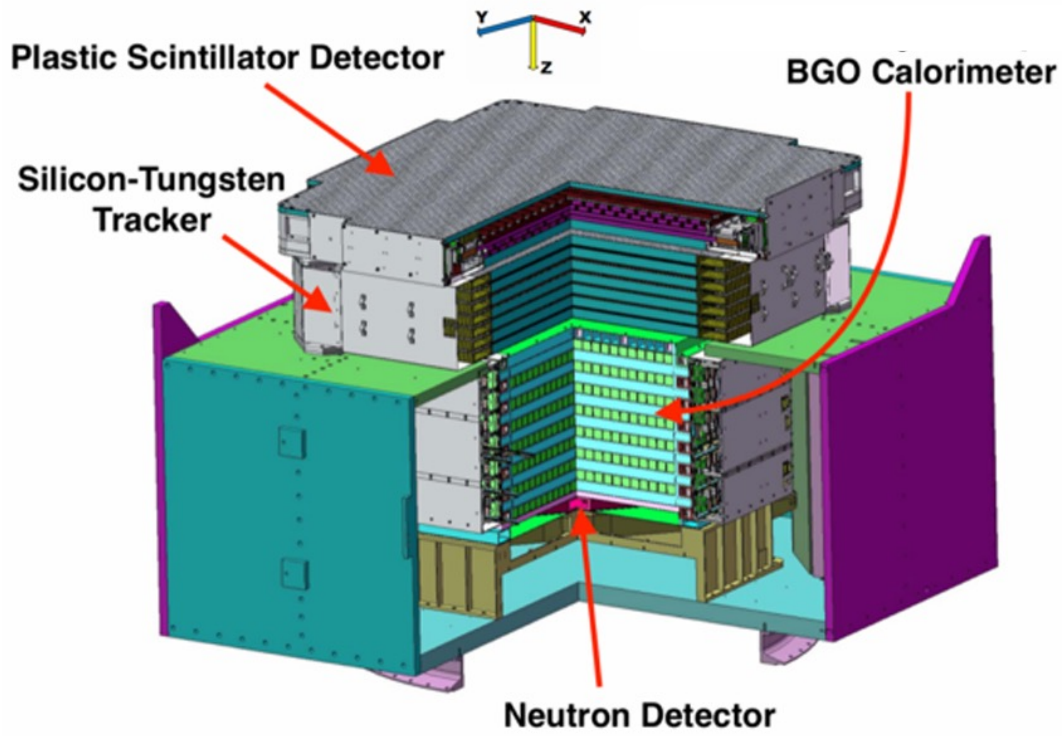




- Gamma-ray bursts (GRBs) have strong connections with **supernovae explosions** and possibly **black-holes formation**.
- It is believed that the **physical processes** in the GRBs include synchrotron, inverse-Compton and photo-pion processes.

Design of VLAST HEIC Detectors

DAMPE: Detector system



Parameter	Value
Energy range (e/γ)	5 GeV to 10 TeV
Energy resolution (e/γ)	1.5% at 100 GeV
Energy range (p/ion)	50 GeV to 500 TeV
Energy resolution (p)	40% at 800 GeV
Geometric factor (e)	0.3 m^2 sr above 30GeV
Angular resolution (γ)	0.1 degree at 100 GeV
Field of view	1.0 sr

PSD: Anti-coincidence detector for gammas and charges measurement
STK: Particle tracker, photon converter & additional charge measurement
BGO: Energy measurement & particle identification via shower topology
NUD: Further particle ID from electromagnetic & hadronic showers

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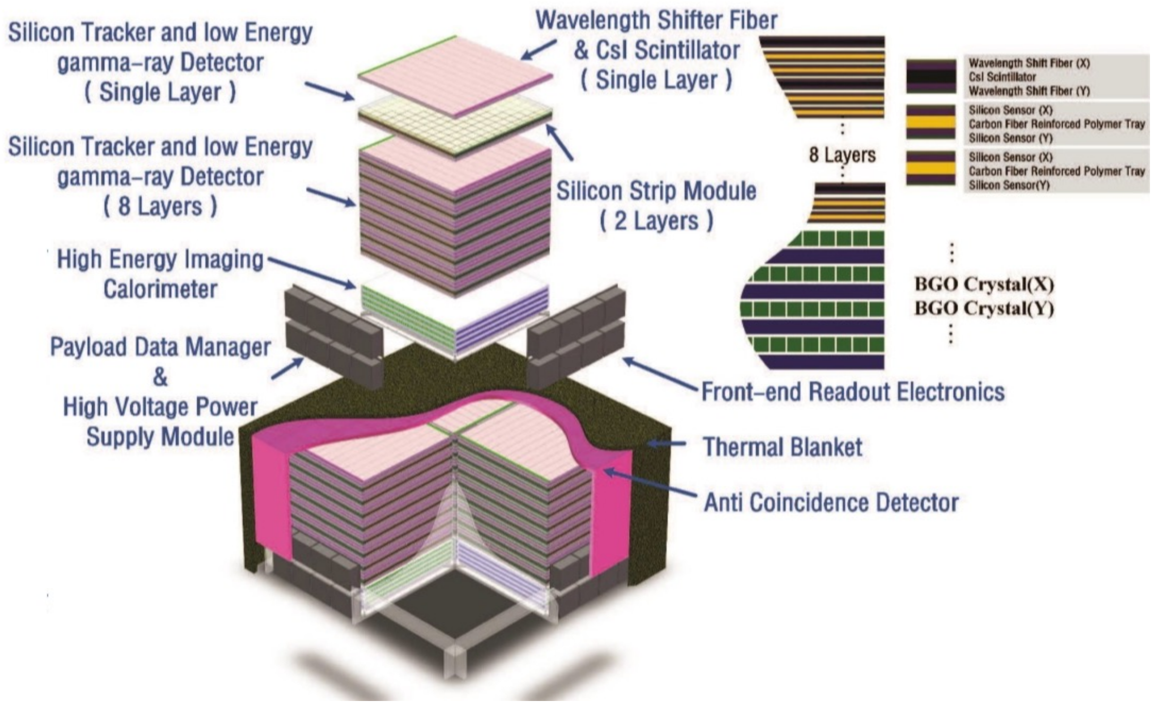
VLAST: Detector system



Parameter	Value
Energy range (e/γ)	1 MeV to 20 TeV
Energy resolution (e/γ)	2% at 100 GeV
Geometric factor (e)	10 m² sr above 30GeV
Angular resolution (γ)	0.03 degree at 100 GeV

Based on the success of DAMPE, the Purple Mountain Observatory proposes the project of **Very Large Area gamma-ray Space Telescope (VLAST)**.

ACD: Anti-coincidence detector for gammas and charges measurement
STED: Particle tracker, photon converter & additional energy measurement for lower energy gammy-ray photons
HEIC: Energy measurement & particle identification via shower topology

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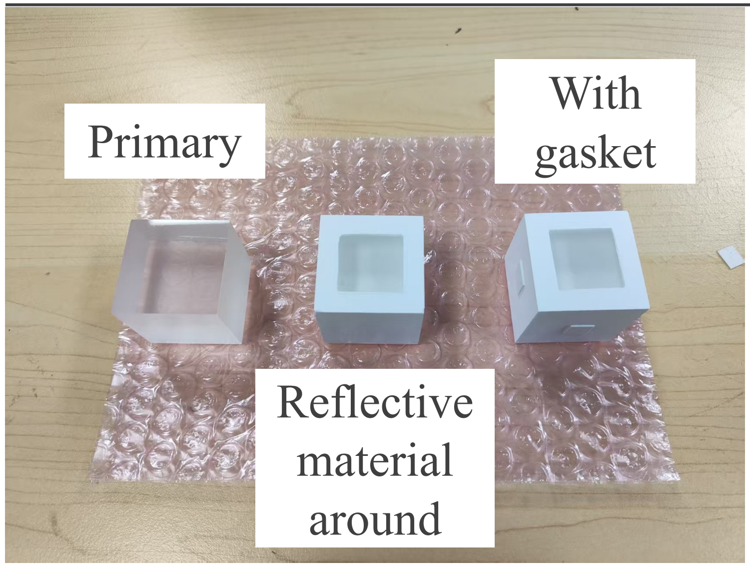
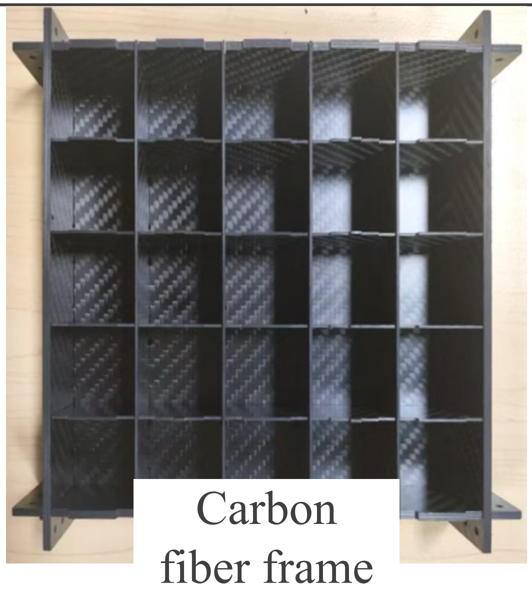
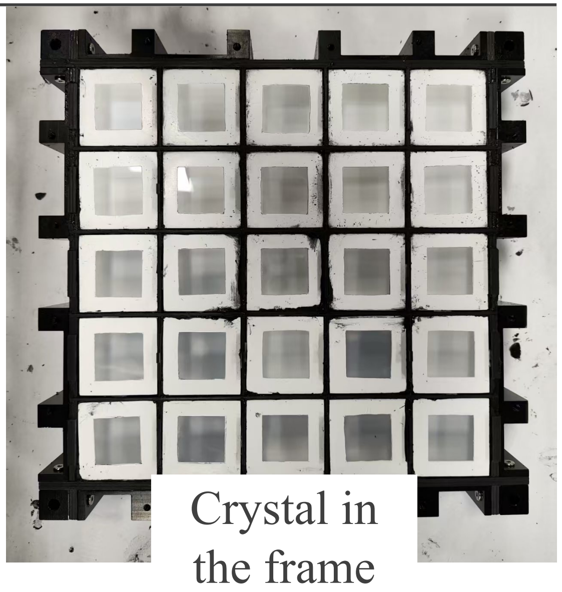
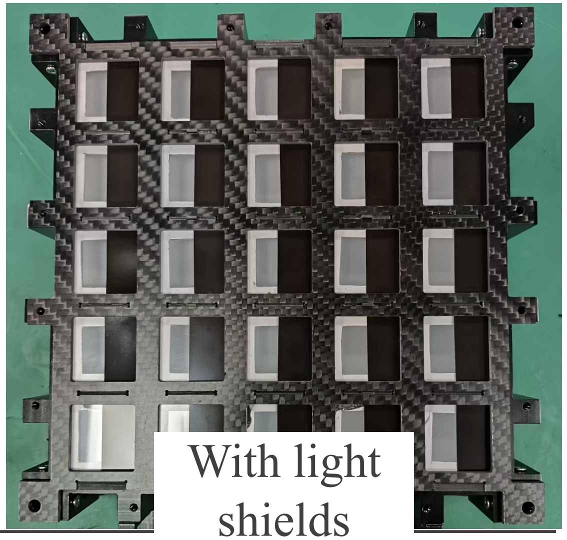
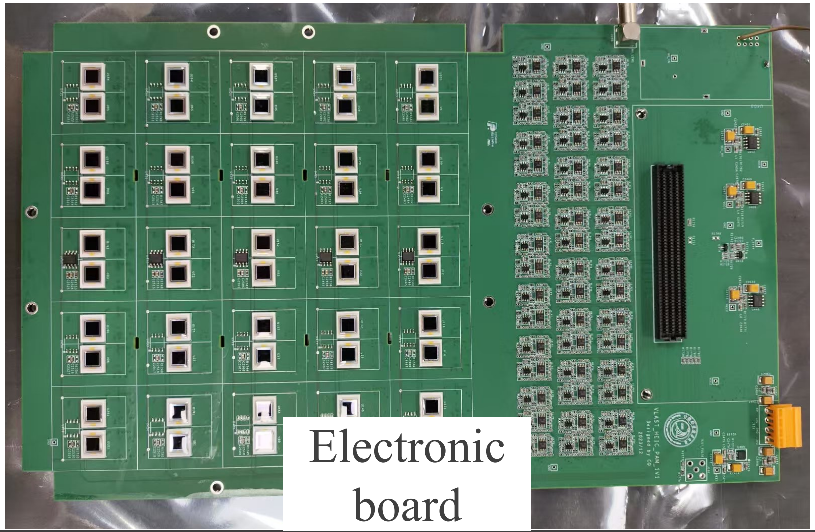
VLAST: HEIC Prototype

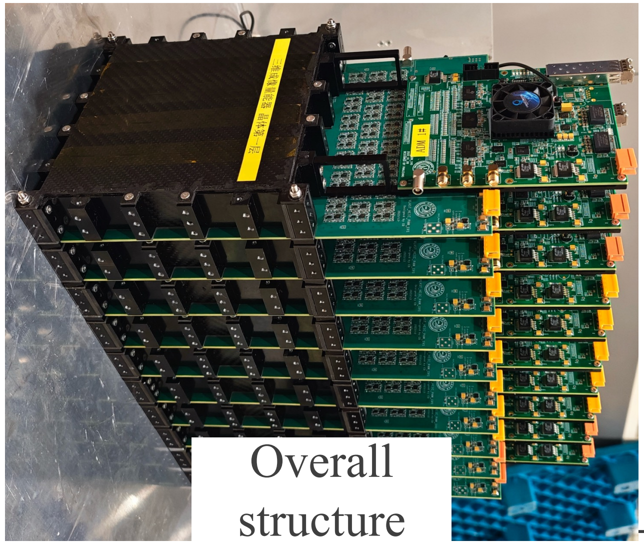






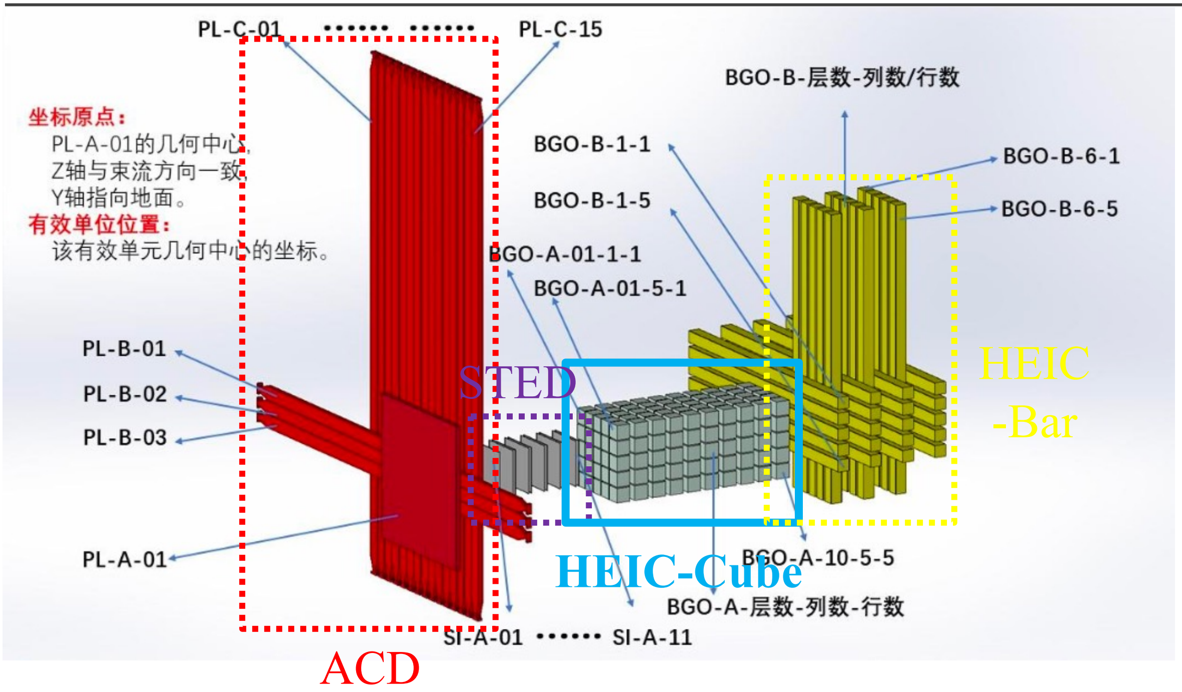


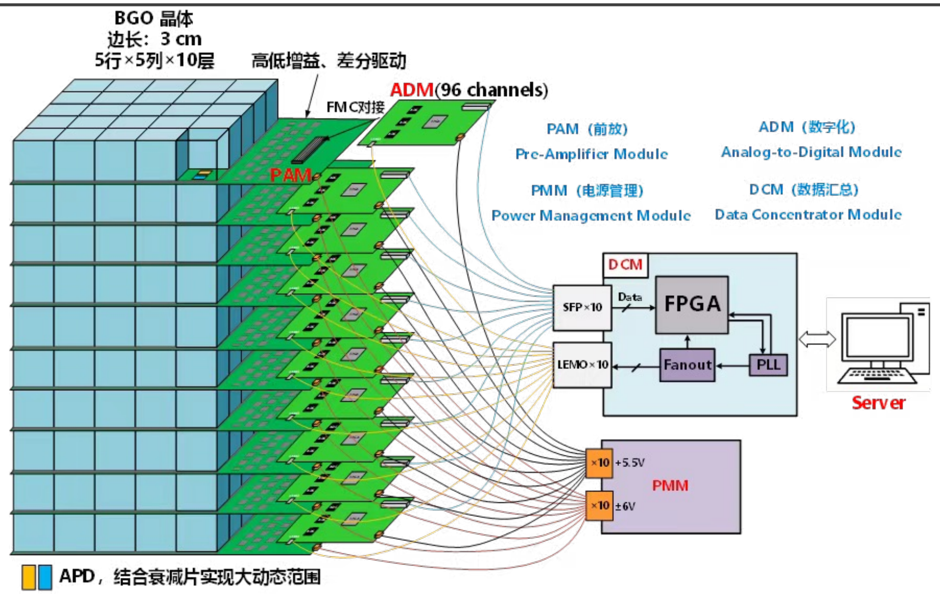




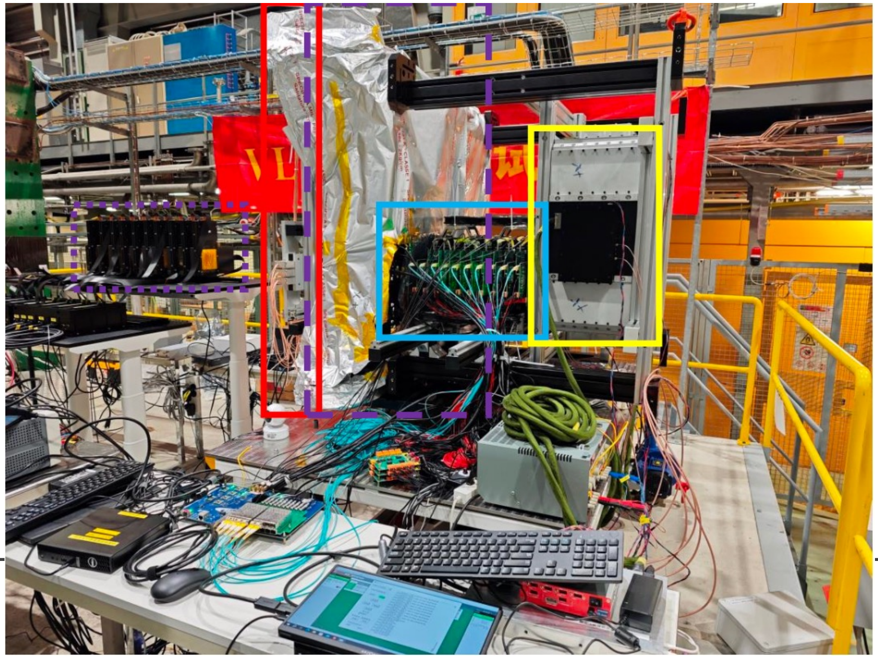
Beam Test in CERN

VLAST Prototype

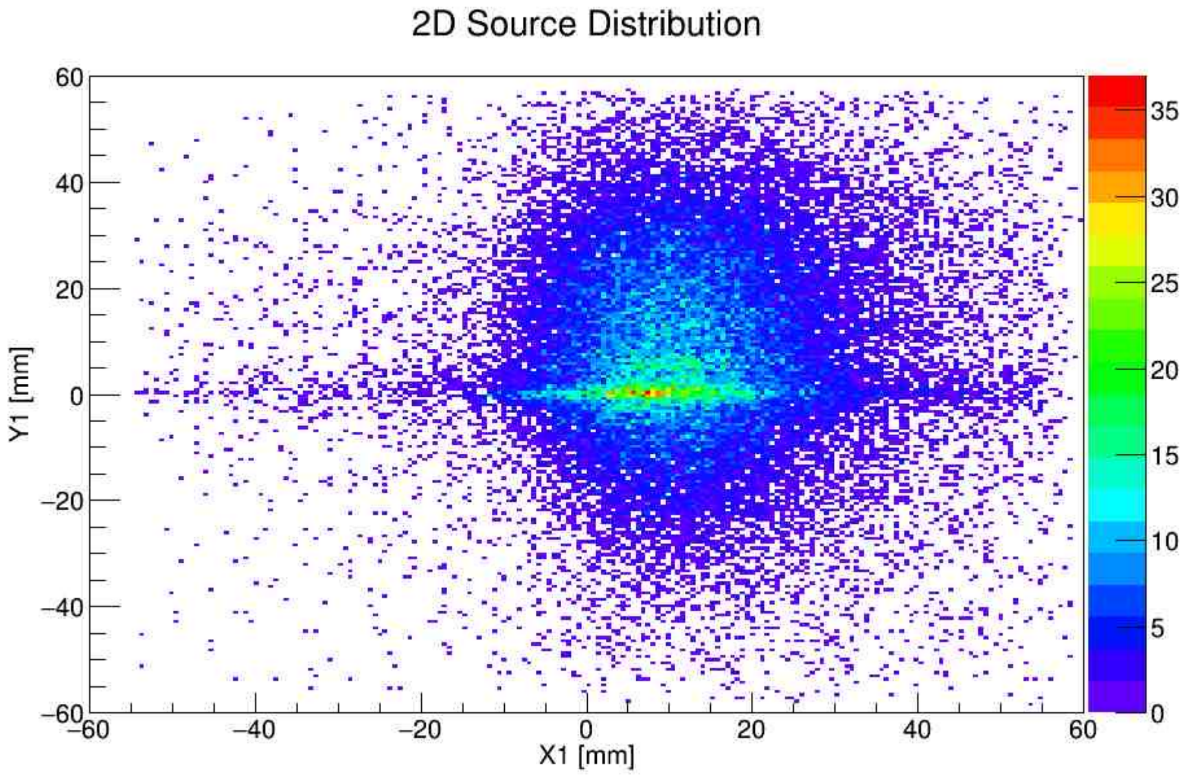


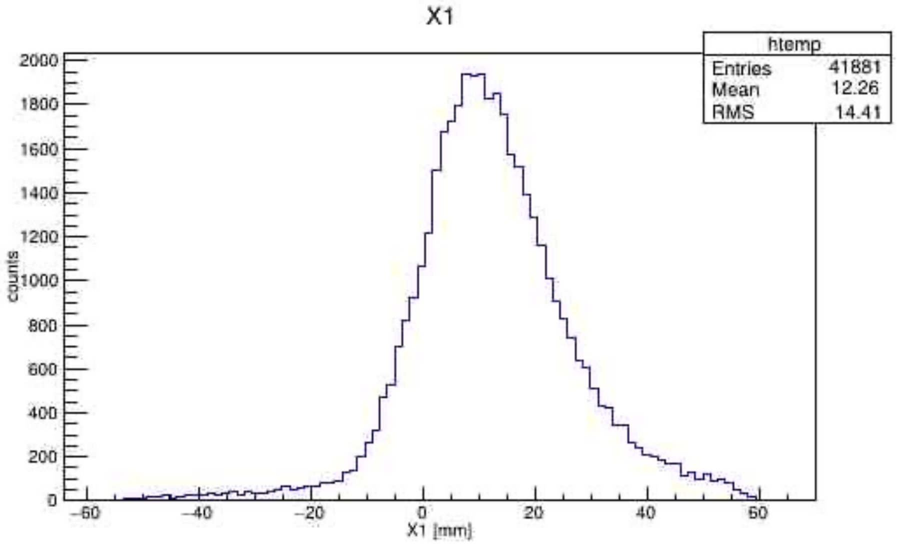


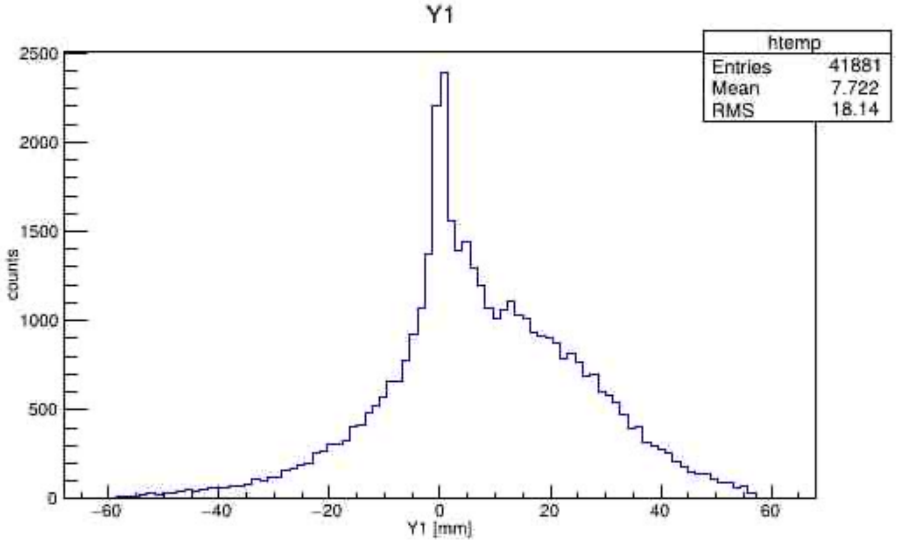
- Beam test is carried out to do some researches on the performance of the detector.
- The size of the 10-layer prototype in beam test is 192mm×192mm×417mm, about 3.3 Moliere radius horizontally and 26.8 radiation length vertically.
- My main work is to analyze the energy deposition of **5GeV electron** in **HEIC-Cube**.



Tracking Information from STED



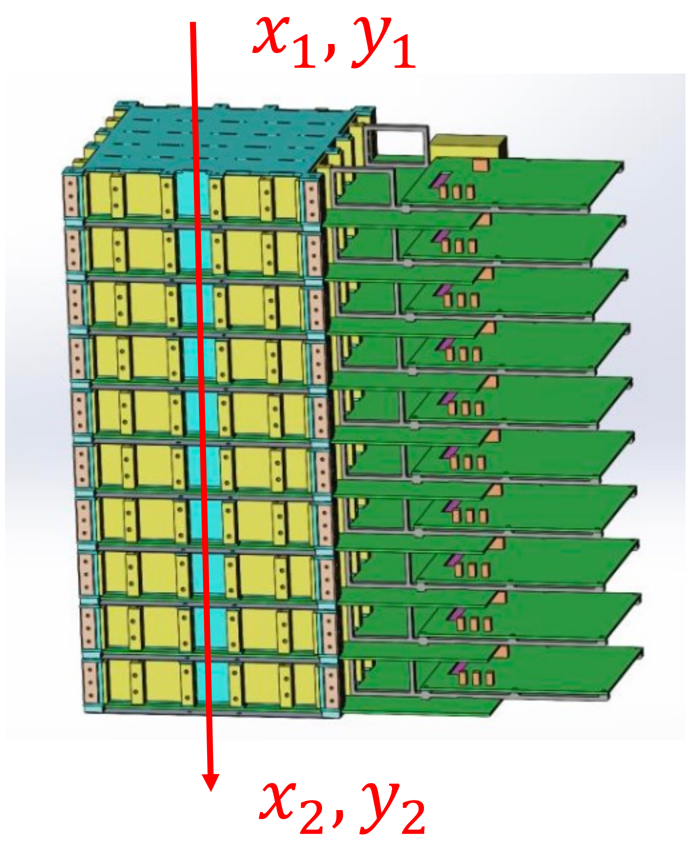




- The figures show the tracking reconstruction results from STED.
- The distribution is similar to 2-dimensional gauss distribution.

Selection Condition

- Selection condition of track:
  - Particles enter the calorimeter from the center of upper surface, and penetrate out from the center of lower surface:
    - $-10mm \leq x_1 \leq 10mm;$
    - $-10mm \leq y_1 \leq 10mm;$
    - $-10mm \leq x_2 \leq 10mm;$
    - $-10mm \leq y_2 \leq 10mm;$
- Selection condition in HEIC:
  - Energy deposition > 5MeV in per unit;
  - Hit Number > 30
  - PID condition:
    - $Edep_2 + Edep_3 > 0.45\ Edep_{tot}$
    - $Edep_9 + Edep_{10} < 0.01\ Edep_{tot}$

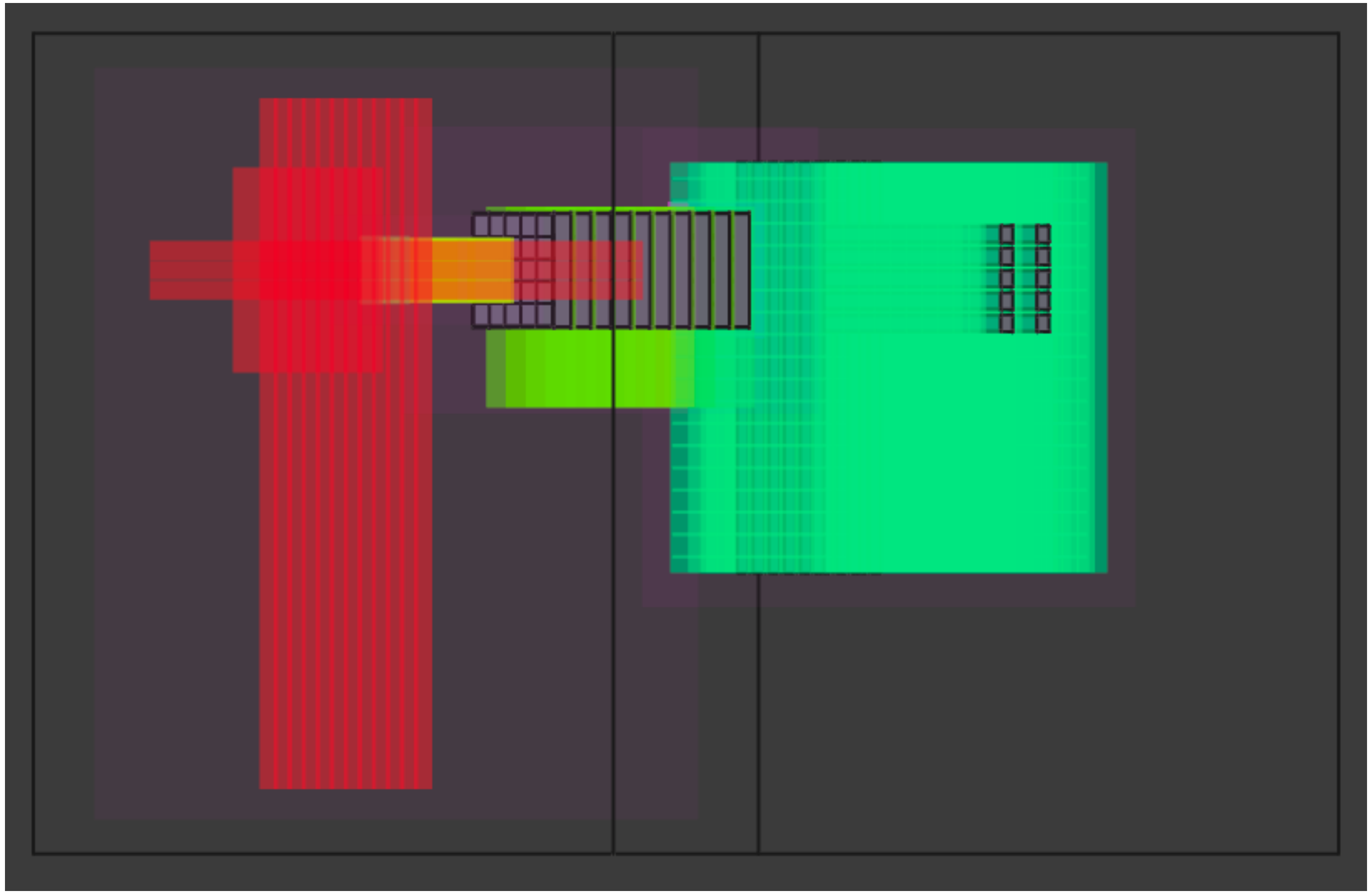


Monto Carlo Simulation and Parameter Digitization

VLAST Offline

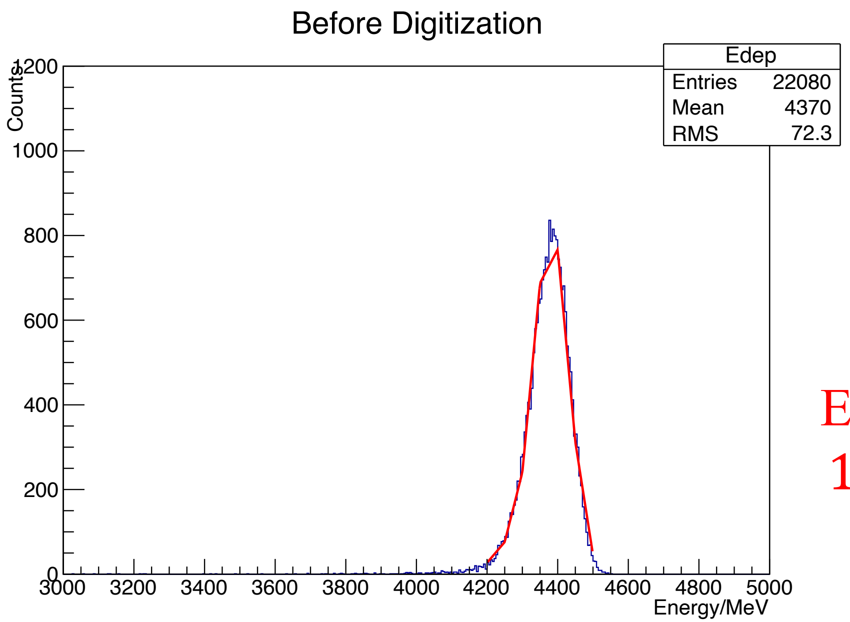
- The offline software system is developed for the offline data processing, including **Monte Carlo** (MC) data production (based on Geant4) as well as experimental data processing and physics analysis.

- The pros and cons of the simulation part of vlast offline:
    - The detectors are almost the same with the real situation
    - No information about the energy deposition of the APD, hard to be digitized

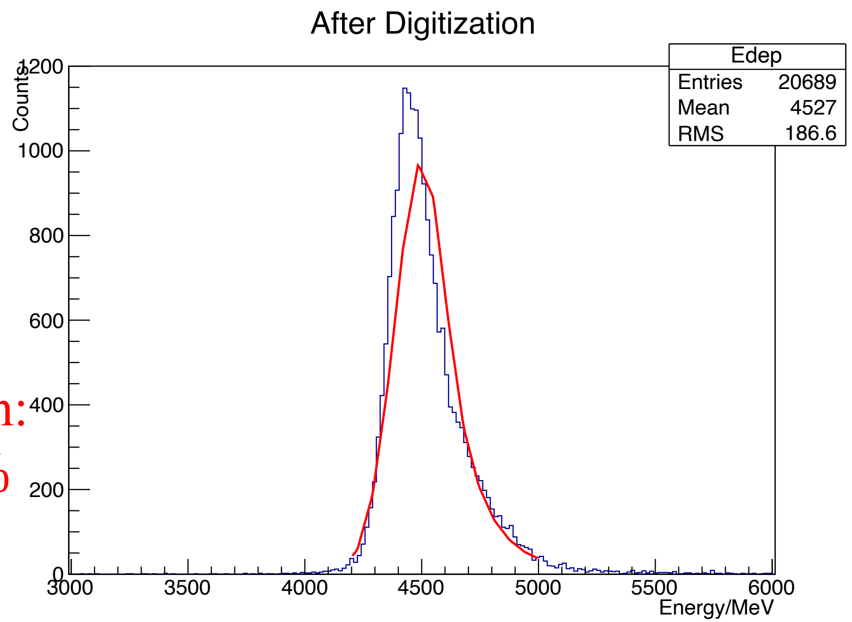


Digitization

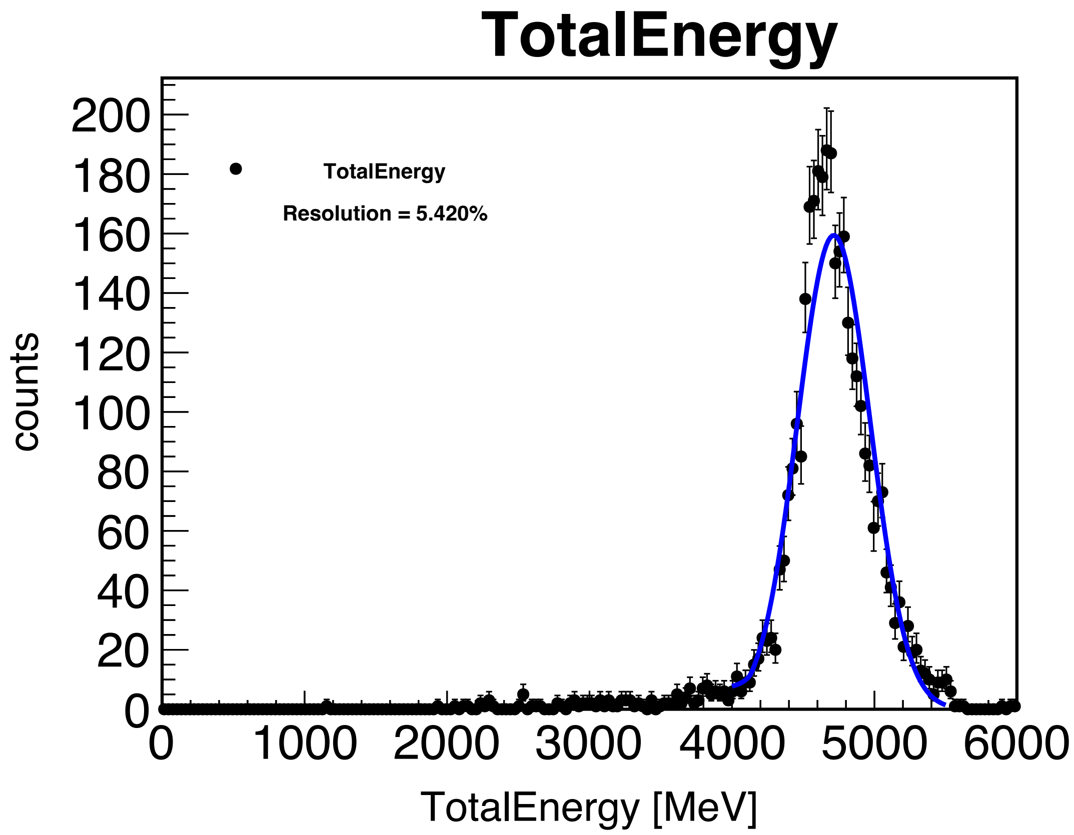
- parameter=mip_mpv/20.576*10000/1.6/50/27.4;
- crystal_p.e.=crystal_energy(MeV)*parameter;
- crystal_p.e.=Gaus(crystal_p.e., sqrt(crystal_p.e.));
- noise_p.e.=Gaus(0, (pedestal_sigma/20.576*10000/1.6/50));
- apd_p.e.=apd_energy(eV)/3.6;
- apd_p.e.=Gaus(apd_p.e., sqrt(apd_p.e.));
- crystal_energy=(crystal_p.e.+noise_p.e.+apd_p.e.)/parameter;

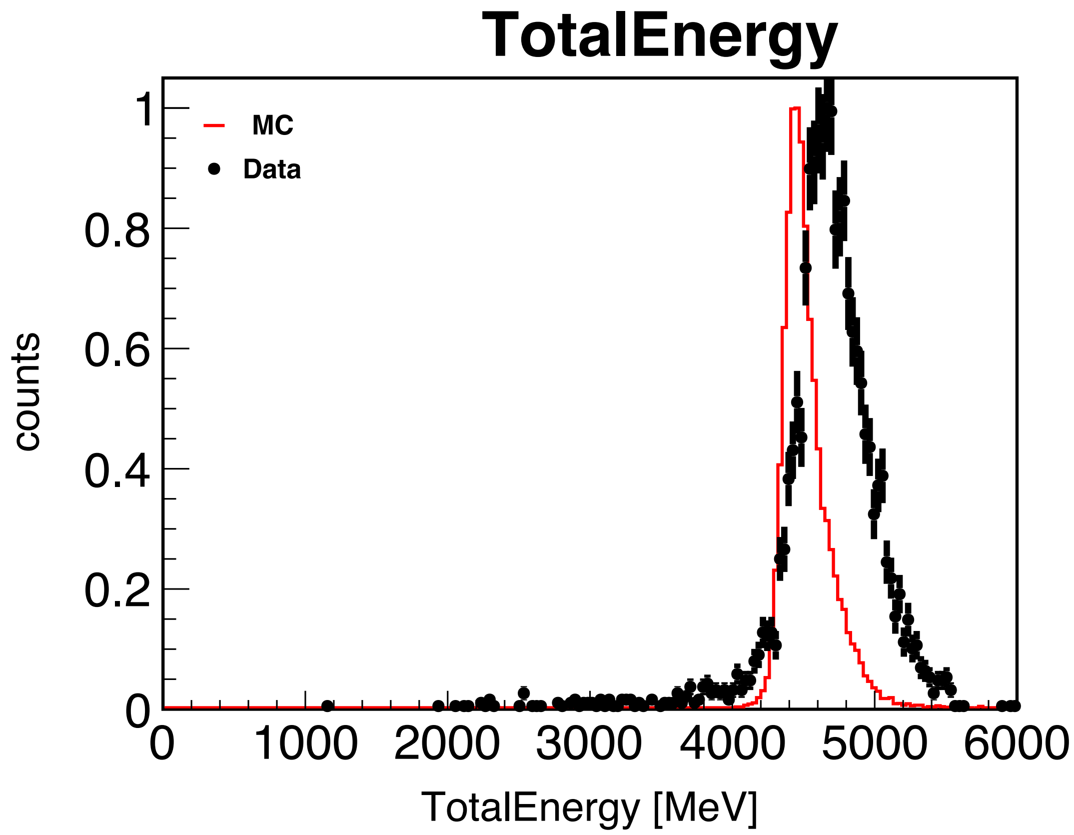


Energy resolution:
1.13% → 2.57%

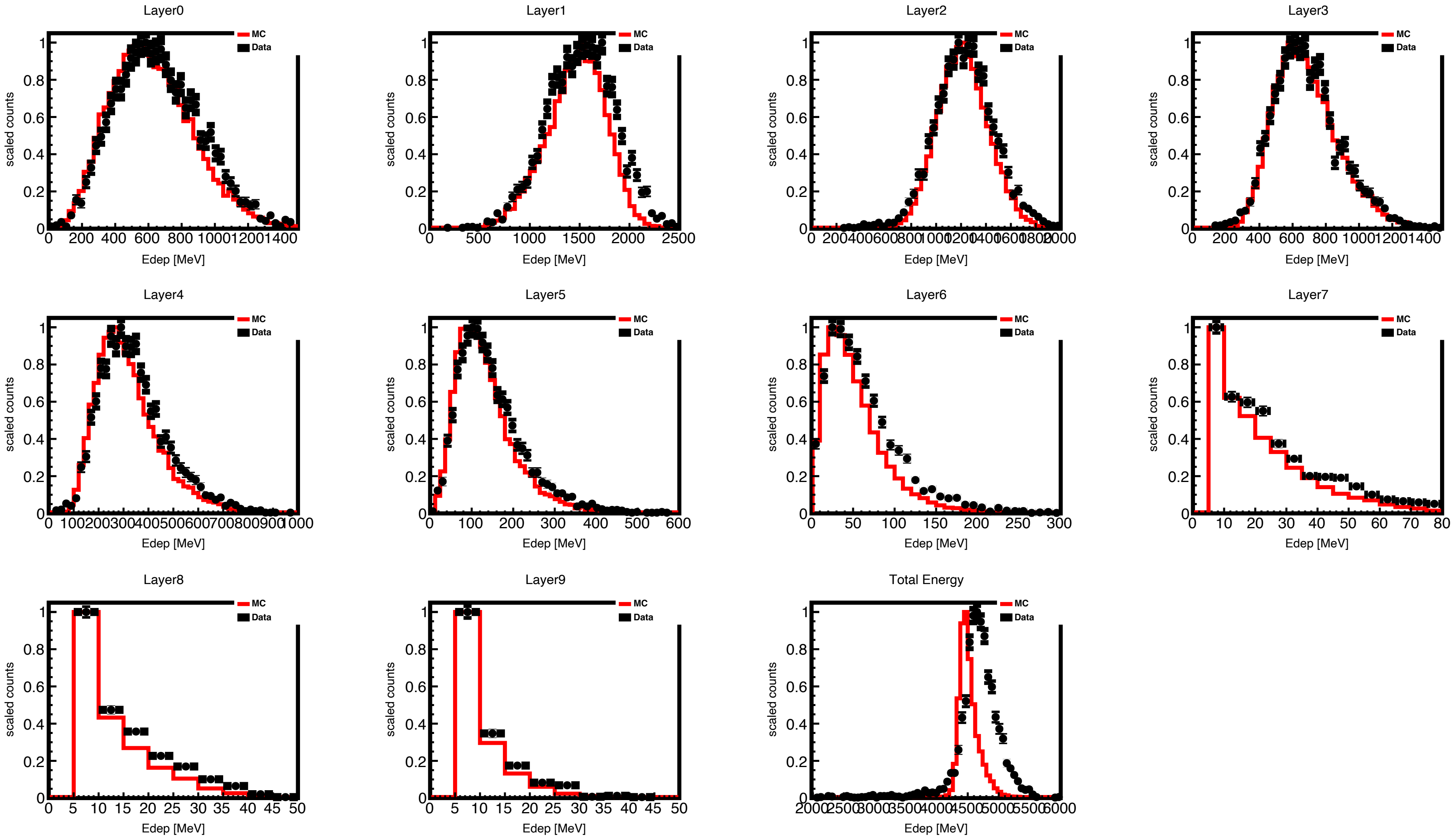


Energy Resolution Comparison





Layer Energy Comparison



Layer Energy Deposition

Summary and Outlook

Summary and Outlook

Summary:

Set selection condition to get close to the real response to the 5 GeV electrons;

Analyzed and compared the results of data from beam test and Monto Carlo simulation;

Made a simple evaluation of the energy resolution of HEIC;

Outlook:

Check the accuracy of the track information from STED;

Alter the source of simulation to the same with beam test;

Improve the process of digitization;

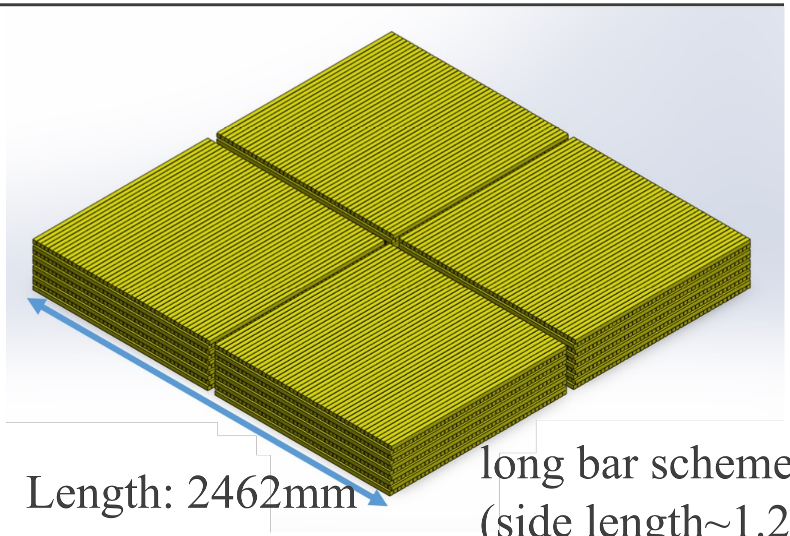
Try to enhance the energy resolution.

Backup

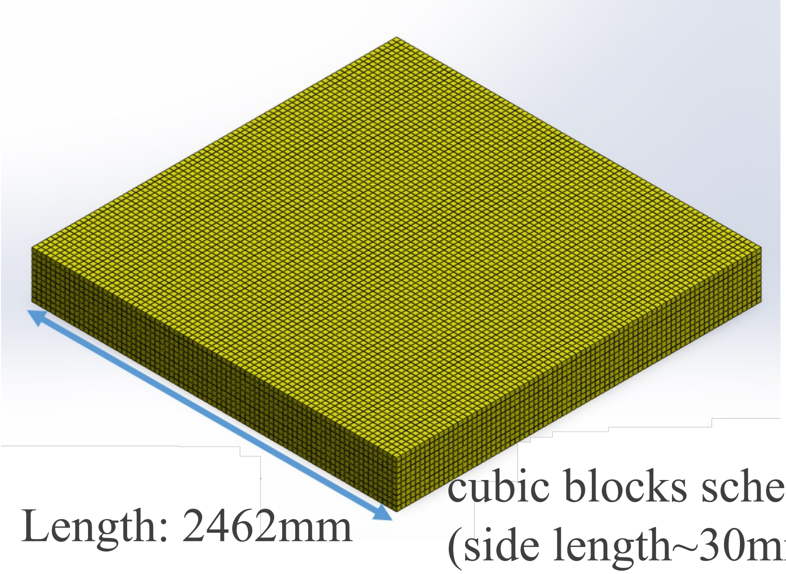
HEIC Cubic Blocks Scheme vs. Long Bar Scheme

1. Effective detection area of every layer: ≥ 2.4 m × 2.4 m
2. Energy resolution: better than 2% (@50 GeV)

- Long bars scheme:
  - Less dead area among crystals, better energy resolution;
  - The growth process of long crystals is relatively complicated;
  - High manufacturing cost of a single crystal.
- Cubic blocks scheme:
  - The process is mature and easy to produce and process;
  - Simpler and clearer clustered contours ;
  - No gaps between modules, convenient for larger-scale expansion.

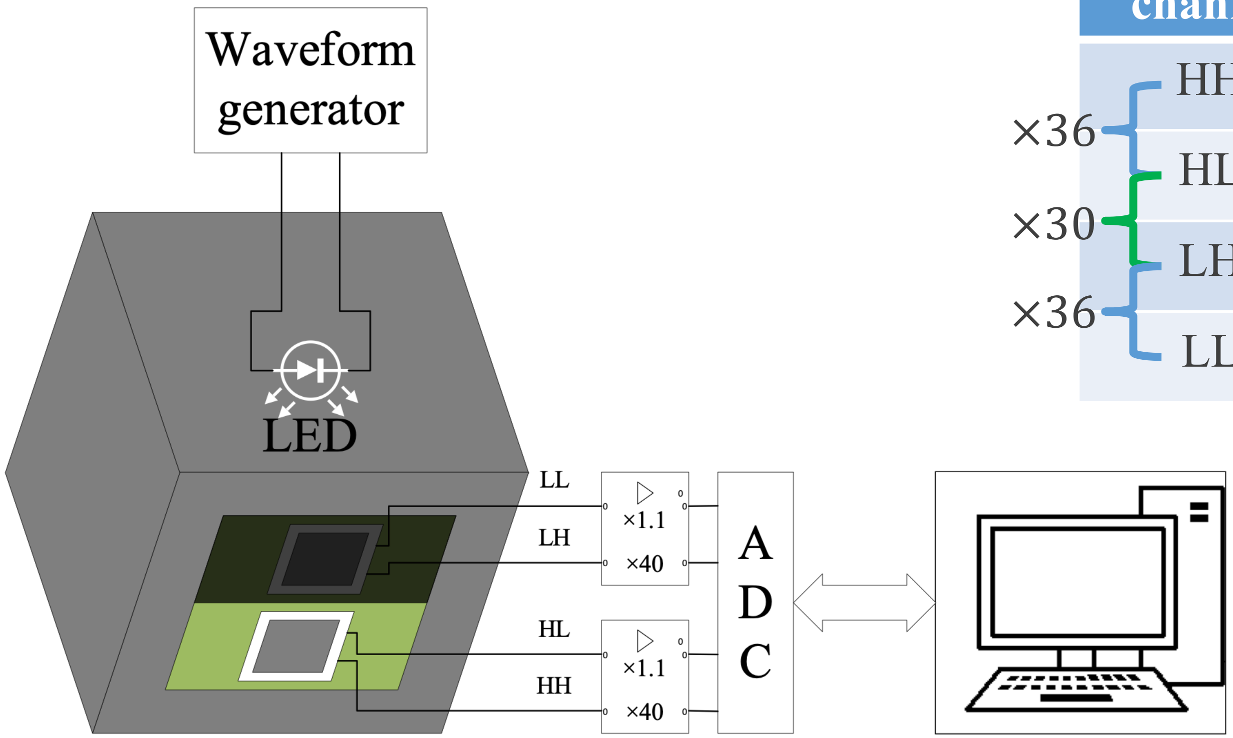


long bar scheme
(side length~1.2m)



cubic blocks scheme
(side length~30mm)

How to Reach Large Dynamic Range



×36
×30
×36

Readout channel	Electronic dynamic range	System dynamic range
HH	3 fC~150 fC	0.1 MIPs~5 MIPs
HL	10 fC~7 pC	0.3 MIPs~240 MIPs
LH	3 fC~150 fC	100 MIPs~5000 MIPs
LL	10 fC~7 pC	330 MIPs~240000 MIPs

With light shields and electronic gain, the dynamic range can be realized:

$$\frac{4096-1000}{5\times10}\times36.46\times31.09\times36.76=2.58\times10^{6}$$